USAF TYPE T-11 MAPPING CAMERA*

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THE Air Force Type T-11 Mapping Camera was designed to fulfill requirements within the military services for a mapping camera to supply precision photography for the photogrammetrist. Besides need to meet the precision requirements, this camera had to be rugged, simple, and easy to operate and maintain from the military standpoint. The general characteristics of the camera are as follows: It utilizes the 6″ $f/6.3$ metrogon lens; it has a shutter speed range from 1/10 to 1/500 of a second; it has data recordings; a shutter synchronizer pulse to actuate external recording devices; and a film capacity of 390 feet of $9\frac{1}{2}$ inch wide film.

Designing these characteristics into a mapping camera in such a way that the precision, ruggedness and simplicity requirements are met, presents a very formidable engineering problem. There are always very obvious and complicated paths to follow in order to have a given design meet a set of precision mapping requirements, and it is only through much thought and redesign that ruggedness and simplicity of equipment are finally forthcoming. To achieve this end in the Type T-11 Camera it was decided to adopt and blend together certain basic features. First of these was to have the precision relationship between the optical elements and focal plane contained in an inner cone and the magazine platen; this was to make possible a camera possessing utmost precision and yet being simple to manufacture, operate, and maintain. The second feature was to use the Rapidyne drawer type shutter; this would permit the utilization of a high speed, efficient intralens shutter that could be removed from the lens cone without disturbing the optical elements. The third and very important feature was to strive for use of readily removable compact sub-assemblies throughout the entire camera; this would greatly simplify the camera maintenance problems, thereby increasing the reliability of the camera. When the final camera design incorporating these features was completed, the result was a mapping camera having the precision required by the photogrammetrist, the simplicity desired by the photographer and camera maintenance man and, above all, the ruggedness demanded by its use in military operations.

The camera magazine does not have forward motion compensation. This is made possible by the present day image velocities at mapping altitudes. Should these velocities become great enough to reduce appreciably the quality of the photography, the forward motion compensation feature will be designed into the camera system. The camera magazine as we know it today, contains a divided film compartment, a vacuum sensing and recording device, a removable case drive and the platen, or vacuum back. The divided film compartment was provided to facilitate loading of film into the magazine while in the dark room; this requires only the supply chamber to be loaded in the dark and the remainder of the loading procedure can be accomplished in the daylight. The magazine platen has been carefully designed to provide a film positioning surface that is flat to a tolerance of $\pm 5/10,000$ of an inch. Special reinforcing of this unit assures the photogrammetrist that the film positioning surface will retain its flatness throughout the life of the camera. Located at the vacuum input of the platen is the pressure sensing device which provides the signal for the vacuum recording. This feature in the camera is of considerable importance. It registers an image

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on the aerial negative whenever a pressure difference of one inch or more of mercury exists at the platen. This in turn, provides to the film checker in the Photo Squadron and the photogrammetrist, a simple but accurate check on the vacuum system of the camera. If the vacuum recording appears, then the film flattening system functioned properly. If no vacuum recording appears, then the film checker knows something was wrong with the system and the mission can be reflown. This will eliminate film containing distortions due to insufficient vacuum from being forwarded to the map compilation organization.

Other recordings furnished in the camera are: fiducial markers and film shrinkage markers, the calibrated focal length of the lens to the nearest 1/100 millimeter, the lens and camera serial numbers, altitude above sea level, time of day, negative number and pencil notations as desired. The recordings are placed in the area between the negatives. The fiducial marker adjacent to the recordings has been made larger than the others. This is to indicate which set of recordings applies to which photograph and to indicate the direction of film transport. The numerical recordings are imaged on the film by means of a simple lens system and incandescent light. The fiducial markers, however, utilize both natural and artificial illumination for exposure. An examination of the design of these markers will illustrate how this is accomplished. It will be noted from Figure 1 that the marker consists of two units—a round dot and a "V" shaped notch. The dot is illuminated by artificial light, and the notch receives its illuminations from the light of the terrain image. This combination was selected as a safety factor. The dot is believed to provide the photogrammetrist with the most precise indication of the fiducial marks position. However, having some doubts as to the reliability of incandescent lights, the natural lighted markers were added to give maximum assurance that aerial photography would have fiducial marker recordings. The chamber containing the recorded instruments, counters, etc., is contained within the camera body.

The camera body comprises the inner lens cone, the shutter and the case drive assemblies, the recording chamber, the camera mounting ring and an outer shell. Probably the most important thing that can be brought out at this point is that the outer shell of the camera body provides the necessary structure on which to mount the various sub-assemblies. This eliminates the need of attaching anything, other than the shutter assembly, to the inner lens cone. In this way the inner cone is furnished maximum protection from any force that might introduce distortion, thereby assuring the using organization long camera life between camera calibrations.

The Rapidyne shutter, as before stated, is a drawer type, high speed, high efficiency shutter. Its sequence of operation is somewhat different from most conventional shutters, in that it has two complete sets of shutter blades and mechanism. One set of blades and mechanism is called the "*A*" side and the other is called the "*B*" side. Each side has only one function to accomplish at the time of exposure. The "*A*" side is normally closed before exposure while the "*B*" side is normally open. At the instant of exposure the "*A*" blades open, allowing light to pass through the optical system and after a predetermined length of time, corresponding to the shutter speed, the "*B*" blades close. This means that the shutter designer has a much simpler design task, as it is not necessary to control the shutter blade acceleration and speed characteristics through a continuous open-and-close cycle. This greatly reduces the inertia of the various parts which in turn permits a reduction in the size of the parts, etc., until we have the shutter reduced to its present size. Another by-product of this type of design is long shutter life. This results from the fact that the shutter

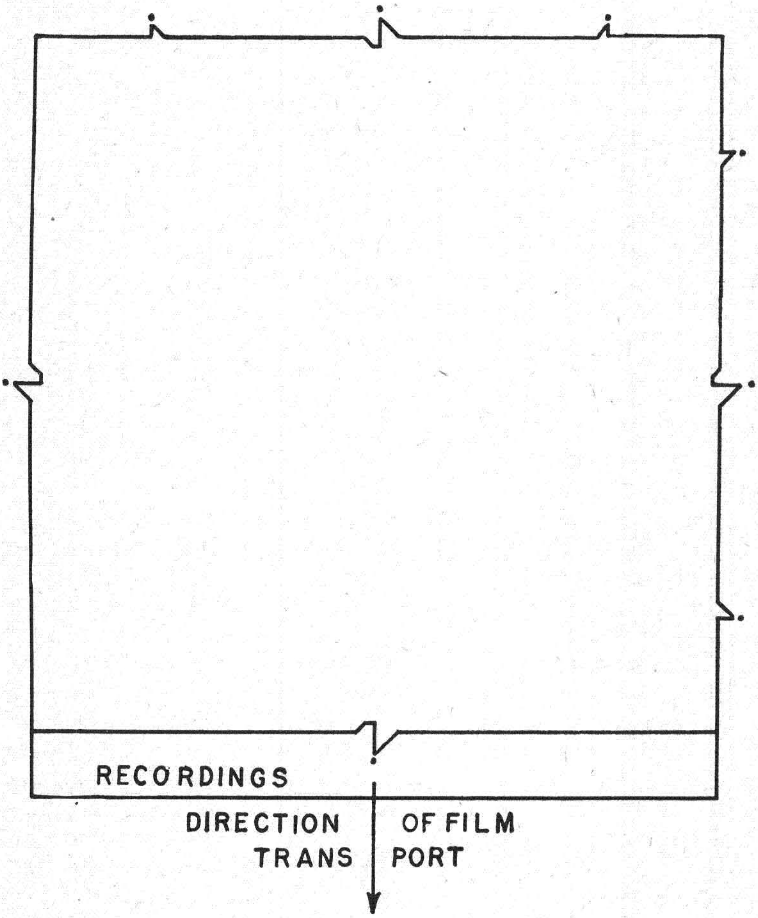

FIG. 1

opening and closing times are constant and only the time between actuation of the "*A*" and "*B*" blades varies. This means that the shutter mechanism works no harder at 1/500 of a second speed than it does at 1/10 of a second, and there is no compromise required in order to obtain the high speeds. The shutter is designed in such a way that the gears, levers, springs, etc., required to provide the motive force to actuate the blades, are contained in an assembly apart from the shutter blades. The blade assembly has been made thin enough to fit between the optical elements of the lens, and is attached to the drive mechanism by means of thin plates and mechanical links. Thus we have the drawer type shutter with the drive mechanism attached to the lens cone, and the shutter blades inserted between the lens elements through an opening in the side of the lens cone.

Another significant feature contained within the shutter assembly is a synchronized switch. This switch is actuated when the shutter leaves of the "*A*" side reach a fully opened position. The pulse resulting from this unit can be utilized to trigger a flash recording system in a remote auxiliary data recorder. In actual tests it has been possible to synchronize the remote recorder with the 1/500 second shutter speed to an accuracy of one millisecond. The speed range of the shutter, as stated before, is 1/10 of a second to 1/500 of a second. This wide range of speeds makes possible the use of the camera under extreme light conditions; subject of course to the limitations of image motion. The camera, having a fixed $f/6.3$ aperture, forces the photographer to operate at the highest possible shutter speed. This combination was selected to minimize the loss of resolution due to higher image velocities present in current high speed aircraft. However, this combination is not without cost, since operating the metrogon lens at the $f/6.3$ aperture does result in some loss of resolution. In order to obtain the highest resolution possible, $f/8$ and $f/11$ Waterhouse stops have been furnished with the camera. These units can be easily attached to the shutter and installed in the lens cone. With this combination available, the photo officer can analyze the problem and select the aperture that will yield the best aerial photography under a given set of conditions.

The last and undoubtedly the most important part of the camera to be discussed is the inner lens cone. This is the "heart" of the camera, for it is in this unit that the precision of the T-11 camera is contained. This unit, when once assembled in its final form and calibrated, is never disassembled again under normal conditions. Should the need arise to disassemble it, this will be done only at the place of manufacture or at a camera repair depot having camera calibration facilities. After reassembly, the lens cone would be calibrated again and, if found satisfactory, would be returned to service.

At this point the design and construction of the lens cone should be examined very carefully. The optical parts supplied by the lens manufacturer have been hand-selected from a large group of lenses for specific radial distortion characteristics. This is required in order to match the distortion characteristics of the map compilation equipment. During the lens manufacturing process every caution is exercised to keep the tangential distortion to an absolute minimum and, when completed, the lens is marked to indicate the direction of the tangential distortion vector. This information is utilized by the camera manufacturer in mounting the lens in the lens cone. The tangential distortion vector is placed in the lens cone to correspond to the direction of film transport which normally is in the line of flight. The reason for orienting the vector in this manner is to minimize the effect of the distortion in control extension by stereo-photogrammetric means. After the camera manufacturer receives the lens, it is assigned to a particular lens cone casting. This casting is designed as one integral unit with the lens attached to one end and the fiducial markers attached to the other, which is the focal plane. This casting is machined to the focal length of the lens. During this process great care and close tolerances are maintained in order to keep the lens elements properly centered, to minimize the tangential distortion, and to keep the lens mounting surfaces parallel to the focal plane. Once the machining of the lens mounting surfaces is completed, the lenses are mounted in the casting and are pinned in such a way as to make impossible the interchange of lens elements.

The next major operation on the lens cone is the installation of the fiducial and film shrinkage markers. These are temporarily attached by means of screws and hand machined to form a film positioning plane flat to $\pm 5/10{,}000$ of an inch. The lens cone is then placed on the lens calibration equipment to photographically check and record the radial distortion of the lens. This process yields the distortion curve, the proper position of the fiducial markers, and the calibrated focal length of the lens. Directly following the calibration, the fiducial markers are repositioned as dictated by the calibration data, and permanently pinned to the lens cone. The lens cone is now a precision instrument. However, the assembly is not complete.

There remains the task of positioning the film shrinkage markers and installation of transparent windows etched with the calibrated focal length and lens serial numbers. These windows provide the means of recording these data on the aerial negative as well as permanently identifying the lens cone. When completed, the lens cone can be installed in any T-11 camera body. If anything should happen to the lens cone while in operational use, the repairman can quickly replace the damaged lens cone with another calibrated lens cone supplied as spare parts, and continue with the project.

When the camera has been completely assembled, it is placed in a standard fiberglass carrying case containing molded Paratex pads. This carrying case, with the pads, represents a major advancement in the aerial photographic equipment field. The case provides complete protection to the equipment against shock due to dropping or tumbling, rain, humidity, sand and dust, salt spray, fungus and even submersion in water.

In operational use the camera can be placed in the Type A-28 gyro stabilized camera mount and also in single-vertical, split vertical or trimetrogon installations. For the multicamera stations, a locating pin is being furnished on the camera mounting ring in order to establish exact azimuth between cameras in a common mount.

To summarize briefly, the present day T-11 mapping camera fulfills all the basic requirements for precision mapping photography taken under normal conditions. The camera has been made precise, simple, rugged and has been furnished maximum protection when not in use. However, with the coming of improvements in lenses, sensitized materials and shutters, and with the requirement for forward motion compensation, this camera will have to take its place on the shelf with its predecessors. Even today new distortion free lenses have been designed and manufactured and it is known that research is being conducted on more stable base materials that might be sensitized for use as aerial film. With such advancements in the field as these, the future should hold much promise for greatly improved aerial surveying equipment and techniques. Until such time as these advancements are realized, the T-11 camera should be a very useful and flexible surveying tool.